THE ECONOMY OF PLANT REPLACEMENT.

Discussion, Birmingham Section.

MR. A. L. TAYLOR : The subject of our discussion to-night, "The Economy of Plant Replacement," is a particularly varied one, as every factory or plant has its own specific problems ; consequently no rigid rules can be observed or applied which could be generally followed. There is, however—in a broad sense—an analogy applicable to all plants and it is from this aspect the subject under consideration is viewed.

If we analyse the important word "Economy" we find such definitions as : (*a*) "Regulations by which things are disposed of" ; (*b*) "Prudence in the use of money and means." We will first consider (*a*) "Regulations by which things are disposed of," as under this definition comes the important one of provision to be made for "replacement of obsolete or worn-out equipment."

A Plant Schedule should in all concerns, whether great or small, take an important place in the scheme of things, as it is from an efficiently kept schedule that adequate provision is made for depreciation of industrial plant. The method of computing depreciation of plant from such a schedule for purpose of replacement by a fixed or variable rate over a given period is unquestionably a complex one, as very careful consideration must be given to each unit or department. It is well known that such plant as engines, boilers, shafting, etc., if properly maintained, has a comparatively long life compared with the majority of production machinery, and it is therefore impossible to apply the same rates of depreciation over the whole.

The principal difficulty in dealing with the question of depreciation arises from the fact that it must be measured year by year during the use of the industrial plant, as the life of a machine varies according to prevailing conditions. It is in this connection that co-operation is needed between engineers and accountants.

If the efficient life of any class of industrial plant began and ended within a period of one year, instead of extending over a longer period, no one would question or suggest that the cost of such a plant was not a necessary charge to the revenue account of that year, and the fact that this outlay on revenue account does not all expire within an exact accounting period of one year is no reason

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for neglecting to refund out of the year's revenue receipts the year's expired portion of the outlay.

It is a misconception to describe the annual provision—that is if any such provision is made—for depreciation of industrial plant as a provision for future renewals, as though it has reference to the future. The annual provision for depreciation has nothing to do with future but relates solely to the past. It is a replacement of capital in respect of past capital outlay expired in the process of carrying on a profit seeking undertaking, and is not less an expense than other expenditure of a current character, such as raw materials, labour, etc. It is an expenditure of exchangeable value incurred daily and must be provided for with other working charges, although the exchangeable value so expended has been acquired and paid for at an earlier date out of moneys provided as capital.

I do not wish to appear to be unnecessarily emphasising this question of adequate provision for depreciation, or as we should say, expired capital outlay, but it is the crux of the question "The replacement of obsolete or worn-out equipment." It cannot be denied that depreciation or expired outlay is as much a part of economic cost as, for instance, the sum paid by the manufacturer for wages. The only difference between the two is that in one the money is paid, or the exchangeable value outlaid, in advance of its use, the objective consideration being realised therefore at a later date; and in the other, the operative's work is received first and the money paid immediately afterwards.

The necessity for treating expired capital outlay as part of economic cost has always been insisted upon by economists. Thus McCulloch, on Political Economy, says: "If the produce derived from an undertaking, after defraying the necessary outlay, be insufficient to replace the capital exhausted, a loss has been incurred; if it is merely sufficient, there is no annual profit." It may be—probably at no distant date—a legal necessity to record with full details the amount of the provision made for annual expired capital outlay with the same scrupulous care and accuracy as other transactions involving current receipt and payment of money.

Having provided the money and means for plant replacement by a properly controlled depreciation fund, let us now consider the other aspect of economy.

Prudence in the use of money and means.

Nowadays one reads and hears a good deal of efficiency in industry, workshop efficiency and production. In other words, the particular commodity must be manufactured under the most efficient conditions and the production from particular machines or other plant must be kept at a maximum value. To attain this

ideal state means very much more than the intelligent selection of a particular machine or machines for the production of any component or article, important as this question of machine selection is. Other factors include ventilation, cleanliness, orderliness, lighting, and supply of incidentals necessary for the operatives, etc.

Generally the chief reasons for purchasing new plant and equipment may be summarised under the following headings: (1) Replacement of obsolete or worn-out equipment; (2) Increasing output; (3) Improving quality of product, or production conditions.

It should be appreciated at the outset that the dominating factor in considering obsolescence of plant is not necessarily a question of age or wear and tear—whether the plant is in actual use or not—but the advance of obsolescence due to new developments and other changes, offering the possibility of replacement to advantage. When considering the replacement of machines by reason of obsolescence one naturally desires to increase the production or output over and above the machine or plant being replaced. It is in this connection that it is essential for co-operation between users and machine tool and equipment suppliers.

If, for example, one has under consideration a grinding proposition the question arises as to whether one should possibly (*a*) plunge-cut grind; (*b*) longitudinally grind; (*c*) centreless grind.

If drilling, as to whether to use: (*a*) plain sensitive drills; (*b*) multi-spindle drills; (*c*) special purpose drills, or a multi drill head fitted to ordinary plain drilling machine.

If press work, whether the most suitable is: (*a*) friction screw type; (*b*) toggle type; (*c*) fixed or adjustable strokes; (*d*) multi slide press, and whether friction or roll or any other type of automatic feed can be economically used.

If bar or chucking jobs are under consideration, whether to use capstans or single spindle automatics or multi automatics either for the bar or chucking—as the case may be.

Many factors naturally influence the selection such as design, quantities, easy change-over, and prevailing trade conditions.

Regarding the question of improving production conditions during recent years, the question of converting plant to electrical drive has been to the forefront and the possibilities of improving production conditions by electrification of plant is an important one. Perhaps it may be of interest to mention some of the advantages of electrical drive along general lines. It must be borne in mind that with electrical drive all the various overhead line shafts. belt drives, rope drives, bearings, hangers, couplings, etc., are eliminated. Furthermore, the electrical motor driving each machine is only running when the machine is working, which results in saving of power as compared with belt-drive systems, so that with electrical drive the efficiency of transmission is at a

maximum and power losses at an absolute minimum. All these factors contribute towards a reduction in running costs.

Another very important advantage of electrical drive is the increase of production obtained from the driven machine. This is due largely to the steady drive afforded, there being no speed fluctuations and also to the fact that the machine may be operated at its most economical speed and output. With electrical drive the average speed of the machine is higher, and great conveniences in operation and control are afforded.

The machine and its driving motor may be situated in the best position in the workshop to assist production and transport, whereas with overhead belt drive it has to be situated to give a convenient drive. Control of the machine is simplified as there are no belts to shift, but in most cases simple " start " and " stop " push buttons located in convenient and centralised positions on the machine. It may be that it is necessary to control a sequence of machines and operations from a central point or from a number of important positions. With electrical drive such control is readily and efficiently carried out. Incidentally, electrical drive has enabled correct values to be obtained for H.P. required to drive various machines.

Mr. H. A. Drane (Member of Council): You have heard Mr. Taylor's views from the buyer's standpoint regarding the economy of plant replacement, and I am down to give you the views of a seller of machine tools. For the purpose of discussion this evening the reasons for the purchase of new plant are summarised under three headings: (1) Replacement of obsolete or worn-out plant; (2) Increasing output; (3) Improving quality of product or production conditions.

Replacement of Obsolete or Worn-out Plant.

It is known that in many instances users do not make any reserve in their accounts for the purpose of purchasing new machinery. Ultimately the time comes when the whole of the plant is obsolete and the replacements necessitate a large outlay. This usually occurs when trade conditions make the expenditure of such sums extremely difficult. It is known that when trade is bad consideration cannot be given to the purchase of new machinery, and when trade improves what money is available too often has to go to the financing of the work in progress. I am convinced that such users cannot combat the competition that they must meet from efficiently equipped works.

Many old-established firms are using obsolete machinery and equipment simply because their liquid resources do not permit the purchase of new machinery. To meet this difficulty, many machine tool makers supply new machines on deferred terms of payment,

thus enabling the cost of the new plant to be defrayed wholly or in part out of the savings effected by its use.

Increased Output.

In considering this item one should first decide whether the new plant is to be merely a duplicate of that already installed or whether the increased output will enable special machines or more of the automatic type of machine to be installed to advantage. Generally speaking, in this country the requirements of engineering concerns are met by the installation of standard machines which are easily convertible to deal with a wide range of work and—a very important point—the changes in the design of the product.

This is largely due to the fact that few manufacturers produce any component of a complicated nature in sufficiently large quantities to justify the expense of a machine designed specially for the job. I realise that a certain number of special machine tools are to be found in the motor car industry. Such machines, often equipped with integral jigs and fixtures, are designed to perform a series of operations on the workpiece. The savings in production times are, however, offset by the high initial cost and by the fact that any change in the design of the product may require an entirely new machine.

Undoubtedly the rapid and continual development in the design of standard machine tools, jigs, fixtures, etc., and the improved methods of production, have widened the scope of the standard machine tool and increased its adaptability and productive capacity.

One is often asked is it better to install capstan lathes, or would it pay to install automatic turning machines? One often finds it difficult to know exactly when automatics should be used but, as a guide, if one finds that a machine can be employed without changeover for two days, then it will be a paying proposition.

As an example of the conditions afforded by modern labour-saving machinery, I would like to cite the results obtained by the installation of four small automatic chucking machines for dealing with a certain component. The component had previously been machined on capstan lathes at the rate of 33 per hour, per machine. The four automatics installed were operated by one girl and production increased to 45 per hour, per machine. In mentioning capstans and automatics I am generalising, but the same argument would apply to other classes of machines.

To-day the majority of machine tool makers give production times with quotations for their machines, when suitable drawings are submitted. It is important that when these times are asked for, the print submitted should give complete information, such as amount of material to be machined and finish required on the

various surfaces. This, you will realise, has an important bearing on both time and tools to be recommended.

Improving Quality of Product or Production Conditions.

This is to some extent interconnected with our first two headings; for instance, the plant at present employed may be inaccurate through age, or deficient through design. On the other hand, some refining process may have been introduced such as lapping after grinding, and in this connection I would like to mention the question of inspection and gauge checking, which can now be easily done to the finest degree of accuracy. I know of one interesting case where a measuring machine is used on production all the week and on Sunday all the gauges are checked over. To-day there are machines and instruments available for every requirement, and if machine tool makers are given an opportunity, they can arrange for their specialists to discuss with works managements various methods of dealing with their respective conditions. This is a point which cannot be emphasised too strongly.

Existing plant can often be improved by the addition of new accessories, such as air equipment, which not only increases output, but reduces fatigue. The average chucking time on certain components before air equipment was introduced was in the neighbourhood of sixty-five seconds. To-day seven seconds is the time taken. I am convinced that machine equipment does not always receive proper consideration, and much time could be saved by the installation of subsidiary machines such as arbor presses, tool grinders, and lifting appliances, etc. If consideration is given to this, it will tend to make machine tools more efficient from a production standpoint.

Machine tool makers are often faced with the problem of training operators for their customers on new machines. They realise it is a part of their obligation, but the buyers do not always see that it is to their advantage to keep a record of the operation on the work produced, in case the trained operator should leave their service.

The purchase of a machine tool to-day involves an understanding between the maker and the purchaser that a reasonable amount of service will be given by the maker after the machine has been installed. This arrangement benefits both parties. It must be realised that machine tools need a certain amount of attention. The machine tool maker receives a complaint that a lathe will not turn parallel, which results probably in a long journey having to be taken by a skilled engineer who, on arrival, finds dirt between the spindle flange and the chuck, causing the work to run out of truth.

Machine tool makers endeavour to build their machine tools to the finest degree of accuracy compatible with the work they are required to produce, but often insufficient thought is given by the

buyers to the installation of such machines, causing endless trouble and expense. There are many alternative methods of obtaining an improved product or improving conditions, such as consideration of plano milling as compared with the ordinary planing, and surface grinding as compared with milling, the use of drop stampings to replace forgings or castings, the use of billets as compared with producing work from the bar.

To-day there is a greater demand for machines with self-contained motor drive. When these are used, you do know the power you have available, and also it is a comparatively easy matter to change over your machine shop to a fitting shop, or vice versa, as conditions demand. It is a fact that the most prosperous firms are those who are continually adopting improved methods of production and modern labour-saving tools.

To sum up the advantages from the seller's point of view, we can say the operator who works under ideal conditions earns more wages, production costs are considerably reduced, therefore the manufacturer can offer a cheaper article and so meet competition, and the purchaser can obtain a product at a lower figure, consequently the demand automatically increases. To meet the demand, the manufacturer requires further machines and more operators, so that everybody benefits.

In conclusion I would say that the ultimate object of the machine tool maker is to sell, not machine tools, but production, and since the machine tool maker's own plant consists of machine tools, you are asked to believe that he is in the best position to give service to his customers, the quality of such service being judged by the efficiency obtained in his own works.

Mr. E. P. Edwards (Section President): Referring back to Mr. Taylor's early remarks, he raised, what I think, is a very important question, and that is the fact that depreciation is rather a matter that has gone by than one that concerns the future. He also put forward the suggestion that we may in course of time be legally compelled to cover this item. As you are all aware, the legal conditions in this country are pretty tight with regard to the preparation of balance sheets, but it is always left to the discretion of the directors as to what should be allowed for depreciation. I take it Mr. Taylor's point is that it should not be left to anyone's discretion but should be fixed by law. I am quite sure that if this was the case we should not see so many companies going out of business as we do.

With regard to the question of electric drives, this has been a very vexed question, and one which has in the past always started a certain amount of discussion. On the score of efficiency, I do not believe there is any question about it.

Mr. Drane made reference to the spending of money at an unfortunate time. Of course we always spend money at an unfortunate time, and I agree with his remark that a good many manufacturers, who do not have any amortisation period, wake up suddenly and find they have got to replace their plant to deal with modern conditions, only to discover that the machine tool maker is not in a position to give delivery. Then the manufacturer, or his unfortunate salesman, gets villified because he cannot give delivery of those particular machines. I think the majority of machine tool users are not themselves to blame for this condition, the responsibility being far more on prospective purchasers for lack of foresight.

Mr. Drane mentioned the question of change-over on automatics and similar types of machine, and he also mentioned a two-day period. He did not tell us, although I think it does bear an important relation, what is the time for that change-over. Perhaps later in the evening he may tell us a little more about this.

I would also like to remark on Mr. Drane's notes on details of work, and here I am speaking purely as one connected with the selling of machinery and equipment. I have at times been into clients' works where they have been interested in new machines and asked them all sorts of relevant questions—what they are doing now, the type of machine, the material and what speed it can be cut at, its chemical analysis, etc., but by the time one has fired a few of these questions at them they turn round and say: "We are buying this machine; we expect you to tell us these things!" That is the wrong attitude.

When the machine tool maker comes into your establishment, he comes in with the idea of helping you, and himself, and the more information you can give him the more likely he is to be of real service to you. If you know that a certain material can be, or is being, cut at a known speed, and you tell him that, he is more likely to give you an intelligent time of production than if you leave it to his assumption. He is not always fully aware of the conditions in your shop, and he is then far more likely to give you a correct production time than if you withhold the information. In requiring this information, he is not asking for something he ought not to get from you.

Mr. Drane: Regarding automatics and the question of change-over, I had made some inquiries, and that is why I put that forward. It was checked over and worked out that if a machine could be kept running for approximately two days without change-over—that is, assuming the set-up would not take more than about two hours—it was a paying proposition. It may be remarkable, but I have known batches (I think 18 has been the minimum number of parts) produced on an automatic, and it has paid, but, as I mentioned

before, when you get those small quantities you always put them alongside other articles which require similar operations, and that is the only way that you can make small batches pay. Really it rests with the setter-up to use his judgment. It boils down to the fact that with small batches you do not set up the whole of the machine; you utilise existing tool outfits to do several similar components.

I remember a job that was tooled up to be produced in about two and a half minutes. I saw the machine after it had been running some weeks, and they were producing round about 50 to 60 per hour. A boy was operating the machine, and the production time was so short that it took him all his time to load the machine. A lot depends on the operator.

MR. R. C. FENTON: I happen to be connected with the same firm as Mr. Drane, and I should like to enlarge on the example he gave of machine work, because it was an example where the customer did not give the machine tool maker sufficient information. Actually, the machine was bought on a given production time, and the customer was quite satisfied with the time. Before the machine was delivered, he said he would like to come and see it. He came along and looked at the samples that had been done, and said: "These are too good for the job! Cut out all these finishing cuts—roughing is good enough." If the customer had said that he wanted a one-cut job to start with, time and money would have been saved. Since that time I think the output has been still further improved, and is now somewhere about 80 per hour, due to careful analysis of their castings and to co-operation with the foundry. There is no doubt about it that, from the machine tool seller's point of view, the question of co-operation is very vital.

MR. WHITE: There is a gentleman present from whom I bought six machines about four years ago and have had them running under the conditions specified, operated by girls. These six machines gave a certain output. This gentleman said his new machines would do the job better, so I re-sold him two of these earlier machines and he sold me two new ones. The new machines keep a tool maker, setter and feeder going, and I get 500 gross per week from the two machines with three change-overs a week on each machine. They are doing the work of six machines, and we have still got four of the old machines running as well. That bears out the fact that automatic machines can be changed over three times a week, and these two machines are actually being changed over three times a week and giving the same output as were the six previous machines. The point that the machine tool maker should stress is that he will take obsolete equipment into the exchange cost. Even directors of firms will listen to a proposition of that nature.

Mr. Drane: You mentioned hire purchase arrangements, and of course the purchase of second-hand machinery enables many a man to get some modern machinery which he otherwise would not be able to buy. The poor machine tool maker has only one profit, but the purchaser, if he runs the machine tool properly, gets a profit on every job he produces. That makes all the difference.

Mr. R. H. Youngash: I came this evening feeling that wild horses should not drag me into this discussion. However, since listening to what has been said, I have changed my mind, and rather think that I ought to join in the chorus of acclaim of the machine tool maker and machine tool salesman.

If you examine the balance sheet of any company you will find that one of the important items is the capital value of their plant, and that each year that plant is reduced in value by some amount. That amount does not represent money saved, it merely means a paper transaction in reducing the capital value of that plant, and it is one of the items in a balance sheet which may be successfully used to prove a profit when there is none, but unless there is a profit, you cannot buy new plant, and if we had here this evening the financial directors and other directors of the companies that we all represent, then I think perhaps we might do some useful service in persuading those gentlemen of the economy of plant replacement.

There is only one w[illegible] to get plant replaced—and I am speaking very feelingly now—[illegible] that is to smash it up, and the most successful way to do it is [illegible] a very carefully planned accident with it, and reduce it to a cond[illegible]on when there is no question about it, it must be replaced.

There are so many pro's and con's that I agree with Mr. Taylor that there is no hard and fast rule; you cannot make a rule on a question of this sort.

An interesting condition has been brought to my notice quite recently where an electrical plant producing something in the neighbourhood of 3,000 electrical h.p. is under consideration for being scrapped. This plant has been working for twenty-one years, and it is working to-day, and the proposition that is before the owners is to throw it away and put in Corporation current. They can buy current through the Corporation at a price which perhaps we might say for the sake of argument is .6d. per unit, but the plant they have has been reduced in value by continually writing it down until the capital cost is literally gone, and the production of current from that particular plant is costing them .4d. There you have a problem that is rather a difficult one to solve, and nothing short of busting that plant up will replace it.

We have heard Mr. Groocock tell a story about plant that could not be replaced under any circumstances by other plant which would produce the work more cheaply. It may economise in floor space,

but if the floor space is not important, then the possible economy of floor space is not sufficient inducement to spend money on new plant. So you come down every time to a consideration of ways and means of providing money for it.

My own experience goes to show that it is much easier to get plant for new pieces than it is to even talk about getting new plant for old pieces. The whole thing is so bound up with economic conditions that it is impossible to lay down even the most elementary rules.

I can remember that on one occasion I joined the staff of a company which had recently been reorganised after some very serious financial difficulties, and conditions were so stringent that we could not even buy for our tool stores drills of the larger sizes, perhaps above $\frac{1}{2}$ in., with $\frac{1}{16}$ in. jumps between sizes. We had an old blacksmith, whom we set to work to make a lot of flat drill blanks, and when we wanted a drill $\frac{1}{16}$ in. difference of size, we ground up one of these, and used it for the job. There was no economy of labour in that, but there was a very definite economy of money, and in a couple of years that company was on such an improved financial footing that it was able to buy drills.

There are many aspects, of course, that have been discussed and will be discussed further. This question, for instance, of electrical drives for machines. Personally, I welcome the change on to machines with self-contained drive, and no overhead gear—at least, I should have welcomed it, but my company, having taken down all overhead gear, have proceeded to put conveyors up in the air, and so stuff up the space again!

There is one very serious drawback with electrical drives, that is, the inability to readily change in small degrees the speed of revolution. It is a serious drawback. It often involves making a new train of gears, and the advantage of having a positive drive is very often considerably nullified by the fact that one cannot readily vary the speed to suit differing conditions and materials.

One of the difficulties to do with replacement of machine tools lies very largely in the hands of the machine tool maker. They are continually improving machines until they will do everything but talk. That, perhaps, is fortunate, since there are plenty of others who can do all the talking that is wanted, but the improvements they incorporate may be perfectly useful to some users but are useless to others. Their difficulty is that they have to make the machine suitable for many different articles of manufacture, and they endeavour to cover the largest range that they possibly can, but in doing so they make the machines more and more expensive, and an expensive machine starts the question of replacement value, because if you have an inexpensive machine which does the job in a certain time, unless you can show a tremendously large saving

from some expensive machine, you can so burden it with overhead costs that your final end is—as you were.

You have not only the question of capital expenditure, and all that that means, you have the question of maintenance, the question of more highly skilled operators : many points like that arise which, I think, go a long way towards nullifying the advantages which apparently accrue from replacing one machine by another.

Mr. E. W. FIELD (Member of Council) : I deplore the suggestion Mr. Youngash has put forward. Please do not break up your machines ! If they are so obsolete, the wreckers will not give you anything for them ; they will eventually come back to the machine tool makers to be repaired.

I should like to increase the scope of the question which Mr. Drane raised—the question of service. He very nicely used the term : "The machine tool maker gives a reasonable amount of service." Having had a fair amount of experience on the user's side, and perhaps a little more experience on the manufacturing side, I should like to know what "a reasonable amount of service" is ? A letter came to my company the other day reading as follows : "Dear Sirs.—No doubt you recollect that in 1920 you sold us a ———— machine. That machine has given excellent service, but unfortunately our operator died last week. Will you please send a demonstrator." Is that reasonable service ?

The use of old-fashioned machines is exemplified in the textile industry, and probably the machines are cheaper per piece in this than in any industry in this country. It is an education to go round a textile machinery factory, where they still sell their products at so much per ton. Design and so on hardly enter into it. Competition forces them to sell a loom at so much per ton, irrespective of the modern requirements it has got to meet. It is a custom of the trade.

One other point I should like to stress is that we are talking principally of the economy of plant replacement. With very few exceptions, any one who understands the use of modern types of machines is largely struck by the inefficiency of the customer in using what machines he has got. In many cases the increased production that he actually wants can be obtained from existing machines, provided he has an equipment engineer, who really understood modern tooling methods.

We had an informal discussion some years ago in which Mr. Lang made the statement that he had been round a considerable number of factories in this country and on the Continent, and had never seen a combination turret lathe efficiently run. That is a slight exaggeration, but the percentage is very low. I think if we take the matter a stage further we must all agree that the most common of all machine tools, the centre lathe, is very rarely used

efficiently. More production could easily be obtained from existing plant by a little attention to equipment details.

Mr. Drane : Mr. Youngash raises the question of skilled operators on expensive machines. I am always led to think that with modern machines a skilled operator does not always enter into it, because generally speaking, if you compare, say, the centre lathe with the turret lathe, it has been proved that you do get from a capstan or combination turret lathe a better output if the man is not too skilled, as a centre lathe operator uses his ability perhaps too much and forgets that the machine will help him to do the job. I know definitely that on a turret lathe a skilled operator does not get the same output as a semi-skilled man. I will go just a step further and say that I once saw a very expensive machine, a combination turret lathe, and in the top of the turret was a wooden tray in which the man had placed all his tools, including a dead centre ! That man was a skilled man and did not know how to use that expensive machine.

With regard to "reasonable service" ; no one knows better than Mr. Field what that is. We are all up against it. Another point raised in Mr. Youngash's remarks was the question of floor space. I always thought that floor space was most important, and that if you could get into the same area something that would increase the output, say, 50%, the overheads would be less.

Mr. Youngash : With regard to the question of skilled labour, I believe I said "more skilled." The point I had in mind was that you might have a small machine—a single spindle drill—worked by female labour, take it out and put in a heavier machine—multi-spindle type—where you would be obliged to employ a man. You cannot escape that. With regard to floor space, I venture to suggest that its value depends entirely on whether you want it or not. There is no useful purpose to be served by emptying half your shop unless you have something to put into it.

Mr. G. H. Wray : Mr. Taylor mentioned one of the most important aspects of this subject, and that is depreciation. Depreciation can be looked at in two ways. Say a machine is worth £1,000, and it is fully depreciated in ten years by the direct method of £100 per year. In the first case, it can simply be depreciated on the books, and at the end of ten years, the machine has no value on the books, and there is no money available for the purchase of a new machine. In the second case, if the amount of depreciation were set on one side, then in ten years, there would be £1,000 to buy another machine. This case is stated in this manner for simplicity but, of course, interest and income tax will have to be taken care of. If money is set aside in this manner to take care of

the depreciation, then in hard times there is money available to spend on new equipment, which will soon bring you into better times.

Mr. H. G. Ramsell : I should just like to say a few words about depreciation. In my opinion it is a wise plan to take the depreciation percentages allowed by the Inland Revenue authorities for income tax purposes, and, in the year that a machine is obsoleted, or replaced, the whole of the balance on the books should be taken up in the accounts. A conservative accountant would advocate taking a larger percentage than is allowed by the Inland Revenue, depending upon the probable life of the class of machine. There is a lot to be said for this attitude to the subject. I think it necessary to have an efficient plant register. This should be on the card system, for preference, and the fullest details should be set out on the face of each card. The back of the card could be used for history of the machine, indicating repairs made, troubles experienced, and so on. If thought desirable, such information as the life of belts, etc., could be incorporated. A good register is invaluable when the question of plant replacement arises.

Reference has been made to machines with individual motor drives, and these should be given very careful consideration when plant is being replaced.

Mr. I. H. Wright : I came hoping to get a really definite opinion on this question of depreciation.

Just to put my case concretely, suppose a firm starts off with new machines. At 10% depreciation, in ten years its plant stands at nothing ; it has been written off, presumably, and the capital value of the business has gone down, say 50% in the balance sheet, but the money has not been saved. Where has it gone to ? Has it gone in paying double percentage of profits, or has it disappeared in reducing prices of the product, in competition with other firms whose equipment has been kept up to date ? That is the question. Firms who simply write off depreciation and give a reduced statement of capital value in their balance sheet are walking towards extinction. I would like to know is there is any definite practice, if it is not revealing any secrets.

People who send out an inquiry now for special machines will find that, compared with five years ago, prices of special machines have suffered a peculiar change, the reason being that not many years ago, the machine tool trade was in such a bad condition that they had to take special machines and merely get a turnover on them. Now, fortunately, the machine tool trade is a little more prosperous than it was, and people prefer to stick to standard productions as far as they can, and special machines have now got to be paid for.

I think that in the coming few years special machines will be less fashionable than they were eight or nine years ago.

I am concerned to some extent, as Mr. Drane is, in the discussion of proposals for replacing machines, and in proving the efficiency and economy of machines to replace other machines or to do new work. The question of collaboration between user and maker of machine tools has been mentioned by so many speakers. My recollections of machine tool building and selling extend several years back, and I am sure that, since the War, this collaboration has been improving all the time, and by continually thanking users for the degree of collaboration we have received, the probabilities are that we shall ultimately get the collaboration which we want. I do not think we have done so yet.

Mr. Edwards mentioned the difficulty of getting full information about how the work has previously been done, and people who have been machining a certain piece of a certain material for a long time are certainly able to give a lot of assistance to those who have to make proposals for a new machine. There are certain things that come into that question which are not as fully appreciated as they ought to be.

For instance, we have a certain piece—not too robust a piece—which has been finished to the actual degree of accuracy required by the assembly (which is not always what is shown on the drawings) by methods of two or three cuts in some ordinary machines. The purchaser assumes that the new machine, which he is thinking of buying, by reason of its much greater horse-power and much larger capacity, is going to do that in one cut, but this is seldom so. This is a strange impression among users of machines, the fact being that the accuracy of the work produced is inversely as the rate of metal removal, and these attempts to use a machine which is going to take it off in one are generally doomed to disappointment.

A very difficult factor to estimate in this connection is the value of auxiliary movements, and relieving the operator. Very often those things do not, apparently, in an ordinary estimate show a very great saving of time, but how can we estimate the effect (probably more physiological than psychological) in the case of a man who performs an operation with a lot of heavy muscular work compared where a compressed air chuck is used, or a carriage worked by an electric motor? What effect will that have in the course of a week?

Mr. Drane and Mr. Field have refused to specify what service is. Here is an example. A small simple machine was supplied, driven by a cone and back gear, as all simple lathes were fifty years ago. Soon after it was delivered, the customer sent for a service man as the spindle would not rotate at all. The service man went (he had

to go 100 miles) and found that the cone was engaged to the spindle and the back gear was in!

On this question of attention and maintenance, as machines get to have more complications in the way of auxiliary movements, and, as I think Mr. Youngash said, have seven-valve wireless sets inside them, it must be appreciated that attention and maintenance is going to be a much more serious thing. Now we have compressed air, hydraulic feeds (quite convenient some of them) and electrical gear carried to the nth degree, the user will in time have to develop a better maintenance for these special phases of maintenance work and I think that when they do that it will very much soften the opinions of Mr. Drane and Mr. Field on this question of service.

Mr. Grew: The question of depreciation seems to be a very vexed one. I venture to suggest that there is no definite progressive rate of depreciation. It depends in many cases very largely on the individuals connected with the management of the company and the product which the factory is making.

I had hoped that somebody would have mentioned the question of repairs and maintenance. If we assume that the depreciation of a machine is going to be 10% per annum, its value is going to be nothing in ten years, but that is not correct. I do not think there is any firm of standing to-day which does not maintain an effective repair and maintenance gang. To take, for instance, the ordinary electric motor, it is not unknown that bearings give out, have to be replaced, and theoretically the value after the machine is repaired is much greater than before, and consequently, if the machine has been depreciated in a certain year by 10%, it is quite possible that 10% has been replaced. I should have liked somebody to mention what happened when an amount of money has been spent on repairs and maintenance to machinery generally.

So far as replacement of plant is concerned, my personal view is that this question of obsolescence and worn-out machinery ought not to arise in a properly organised factory. I should consider the most important factor governing the replacement of machinery should be definitely the improving of the product. The firm or company producing an article which is of the best is the firm which is going to progress. The firm which is producing a bad product, well, it is bad for the workman, bad for the supervisor, bad for the employer. I would have liked, as I said before, some reference to what exactly does happen to all the money that is spent on repairs and maintenance not only on capital, but for tools and machinery.

Mr. Witherford: I have listened with great respect to the older members, and have noticed that the chief subject of discussion appears to be that of depreciation. I think almost every speaker has raised that subject, and it seems to me that there are a number

of angles from which it can be discussed. I believe that we have omitted one very important angle. We all know that the wheels of industry must be kept going, and any firm which, having written off the amount for a certain machine, continues to use that machine without replacing it is committing an immoral act in an industrial sense of the word. Of course, no one can definitely say when that machine must be thrown out, but we might follow the example of the American car manufacturers who make their cars so that in five years they will have to be scrapped.

Mr. Fenton : There is no doubt about it that depreciation varies a great deal in many shops. Depreciation to some extent depends on the management and the care of the machine tools. I have seen machines delivered into shops and have gone along in six months time and shed tears at the way they have been misused. If I had been asked to buy them back, I would not have given 50% of the original price. I have seen other machines in use ten to fifteen years in a condition where you would be pleased to offer a very good price. That, I would suggest to anybody connected with manufacture, is worth considering. If you take internal grinders, for instance, with hydraulic gear, I have seen some machines eight years old still producing excellent work. Some machines, in other shops, after two years are in bad condition, because in one shop there is a definite time allowed every week for cleaning of machines and supervising, and in the other shop the machine is run to death ; it is shut down and left dirty on Saturday, and on Monday morning, without attention, it starts up on production again. If this question of depreciation can be settled in some definite way, then we should also settle some definite policy, as suggested by Mr. Grew, of repair and maintenance.

Mr. Mailin : There has been various mention of the question of electric versus overhead shafting drive, the disadvantage stated about the electric drive being its lack of flexibility. I think it is a mistake to condemn the electric drive because it is not flexible. I do not see any disadvantage in the electric drive ; I think it makes for efficiency.

Mr. Edwards : I, too, rather feel like taking Mr. Youngash to task on this point. After all, whatever way you input power into a machine it is usually by a single speed, whether it is by line shaft or electric motor. I do not think Mr. Youngash would suggest that if you wanted to alter the speed two or three times during a cycle you would stop to put other pulleys on the line shaft. Where you have an electric motor incorporated in the machine, you have exactly the same condition without the troubles attendant on a line shaft, which is an advantage. Further, replying to Mr. Youngash, a speaker has brought the point up that all the necessary

speeds and feeds are usually incorporated in the machine. Would Mr. Youngash like to enlarge on the point ?

MR. YOUNGASH : I was referring more particularly to the type of machine which has a single speed drive. Take a machine which is designed to do some particular operation at some particular speed and you run the machine at that fixed speed, but the slightest variation in the hardness of the material gives a condition where you are either having an extraordinary amount of tool grinding to do to get through a particular batch, or you have to make a number of gears to give you a slightly slower speed. If you take a machine which is equipped with all the changes of speeds, you merely substitute an electric motor for a single-pulley drive ; there are no objections, and, on the contrary, there are no advantages. The electric motor, however, is most frequently coupled direct to the machine and runs at a uniform speed.

In the old days of direct current, we could use variable speed motors, and there are, as you probably know, motors to-day with different sorts of windings in which you get variations, but they add to the complexity of the machine. I do not wish to be understood as making any condemnation of, or objection to electric drives. I merely used that as an illustration of one of their shortcomings.

With regard to this question of depreciation, I think it would be a great pity if we let the gentlemen here present go away this evening with the idea that depreciation is one of the largest factors in the economy of purchasing machine tools. It is not ! Depreciation is a purely paper transaction affecting capital values. If anyone imagines that the directors of any concern walk round and say: " Here is a machine that has been in the shop ten years ; let us scrap it and buy a new one," he is greatly mistaken ; they do not do it. Depreciation alone will never buy new machines, because even the very worst of machines can be made to produce still a little bit more, and it is necessary to have some other inducement than age or depreciation to make one's company buy new machines.

Many arguments have been put forward to-night as to why we should buy them. The principal one is the simplest one—it will produce more work at less cost.

MR. KENDRICK : The last speaker has brought up a point which is rather contradictory. I think that depreciation is not a paper transaction, but in each case the value is of importance. Going away from machine tools, the same thing happens in buying a car. If you buy a car and you hope to part with it in two years, you always consider what value you can get at the end of two years. The same point should be considered when buying machine tools. There are numerous cases where production is not so great, and where the ordinary machine tool will do the job almost as well as an

automatic. Everyoneknows, however, that a good automatic (second-hand and renovated) will fetch a lot more than ordinary machines which cost approxiamately the same amount. On that understanding, if I myself was buying machine tools, I should certainly go for the automatic if I thought I could get a better price for it at the end of three or four years.

Another point was the quaestion of variable speeds on these machines. I do not think that is a serious question. If the user of the machine requires it to be so accurate in its loads and cutting speed, then he will have variable speed gear put on to it.

Machines can be bought to-day with variable speed gear right up to maximum which can be accomodated to belt-driven or motor-driven machines, preferably motor-driven.

Mr. E. T. Cook: First, regarding the variable speed of electric motor-driven machines. That is entirely a question for the machine tool maker. There is absolutely no reason why a small change of speedof the kindwhich Mr. Youngash is referring to, to accommodate variations in material, should not be provided for by a special belt of the pulley type. It is a very simple matter to add a little to a pulley drive. The trouble is to vary the electric motor's speed when the machine is directed through gears, when such an arrangement is not only more expensive but in practice does not work so well. So we must look to the machine tool designers to make some alterations there to meet the requirements of the user.

There is one other question, perhaps the only one, that of depreciation. I do not think any of us have really faced the facts as they really are. Again referring to Mr. Youngash's remarks, he did not refer to the outstanding point which the owner of plant has reference to. Let us suppose you have a machine tool to the value of £100. There is only one thing that matters to the financial man, and that is, how much depreciation the Income Tax people will allow him on that, for this reason, supposing his whole capital is £100, and he is making only £7 10s. per year profit, the amount of depreciation he is allowed on that means he is paying no income tax at all. Take the effect of a 7½% depreciation, that comes directly off taxable income, and therefore he gets a direct personal benefit and advantage by 25% of that amount, almost £2, he does not pay the income tax amount. The higher the value of plant he has got, and the higher the value of that 7½%, the higher the amount he deducts from the income tax he pays, and he puts that to his plant replacement account.

The other question I would refer to is this arbitrary choice of 10% which is a purely internal arrangement and has no real effect on the business. The only thing that means is this, you have a piece of work to do, is there any way in which you can produce that piece more cheaply and at the same time pay for the plant?

THE RELATIVE VALUES OF WHITE AND BLACK HEART MALLEABLE CASTINGS TO PRODUCTION AND SERVICE.

Paper presented to the Institution, Preston Section, by Walter West.

I AM not so much concerned about describing to you the details of manufacturing either black or white heart malleable, but what I do want is to bring to your notice the very great difference there is between the two metals, and to describe some of the fundamental properties of the one as against the other. When addressing gentlemen like yourselves, production must of necessity be the outstanding feature of any remarks, or at any rate, those avenues which contribute to production, and there is only one thing which will do that and it is that you should be able to remove the maximum amount of metal in the minimum amount of time, with the minimum amount of tool destruction.

Now in the first case I want to tell you that black heart malleable fulfills those duties in a very much more marked degree than white heart. For one thing it is very ductile—in a way it is much more easily produced and it comes to you in a better shape. But there is one thing that black heart malleable lacks in efficiency in comparison with white heart, and that is where the metal is subjected to friction or to wear ; in such cases undoubtedly white heart malleable is the better.

In describing to you the relative values, or relative differences, between the two metals, I want to sketch—and I hope in an interesting way—how black heart malleable stands superior to white heart from your point of view. We know that if we take steel, cast iron, or malleable iron, they all belong to the same family, i.e., the family of carbon in iron. The degree to which that carbon is present in the iron makes all the difference to the structure and the properties—those properties which you are so anxious to obtain. There are at least five elements which we must consider if we are dealing with metals of that description, i.e., steel, malleable or cast iron, and each has its respective influence upon the resulting structure or properties, and each is co-relative to the other in producing different phases or different properties to one another as they stand in relation to each other.

It is not my point to bring out these phases or their interchangeability, or the effect of their differences in composition, but rather to show you how between two elements alone—iron and carbon—we get those properties which reflect themselves in the machine shop.

Now by means of common salt solution I want to describe in simile what precisely happens when you have, say, carbon and iron. We know definitely that any solution—it does not matter what it is—by the law of solubility, that solution will dissolve its own maximum amount of any other solid which is soluble in it, and it does not deviate from that, because it is the fundamental law of solution. Let us take ordinary water. We know if we take it at ordinary temperature and add common salt to it no matter how long you might shake it, there is a maximum amount of salt taken up in the solution.

Time becomes a factor of indifference, because the maximum amount of common salt which water will dissolve at room temperature is defined and known at 23.6%. But we know that for every increase in temperature we get an increasing amount of salt into solution, so that if we were to boil the water and bring it up to 100°C. you come to the saturation point of salt in that solution. But if we allow that saturated solution to cool, then out comes that excess of salt from the solution in the shape of flakes, until the temperature falls down again to normal, and you come back to 23.6% in the remaining liquid. This is the amount that water at ordinary temperature will dissolve.

So far we have discussed the power of solution of water for common salt at varying temperatures. Let us now view the relation in another way. We know that water freezes at 0°C., but the presence of common salt in solution causes this point of freezing to be considerably lowered. This is the reason why every housewoman sprinkles salt around the front door when the day is extremely cold. This depression of the freezing point is governed by the amount of salt in the water ; it is proved that this point of freezing can be lowered to the furthermost point of—22°C., and this coincides with a strength of solution of 23.6% in the water. This concentration you will notice is exactly the same amount of salt as that which is taken in solution at ordinary temperature.

Suppose for a moment that we have a 10% solution of common salt in water and the temperature of the solution is lowered to 0°C. We find that while the liquid does not freeze solid, a lowering of temperature by a few more degrees will produce small flakes of pure ice crystals which increase in quantity as the temperature continues to fall until—22°C. is reached, when the whole of the solution solidifies.

As we go along we might follow what happens. The 10% salt solution is a weak one, in other words the water had power to take more salt in solution up to 23.6% at ordinary temperature—the presence of the alkali in solution depressed the freezing point below 0°C. but as the temperature was falling the ice crystals which began to form in increasing quantity really made the resulting liquid stronger, and by this definite law of solidification this process continued until the remaining liquid attained a concentration of 23.6% of salt and it turned to the solid condition. So we have at—22°C. a mixed lot of pure ice crystals and salt water crystals.

Let us suppose the original solution had 23.6% salt in it, then passing from ordinary room temperature through 0°C. to -22°C. nothing would separate, no change at all would take place until at —22°C. the whole would solidify. Here we should have salt water crystals only. Now let out imagination suppose the solution we have to deal with contains an excess of salt, a quantity in excess of 23.6%, for which we need a higher degree than room temperature to make it go into solution. As we have indicated before this evening, as soon as this saturated sloution is allowed to cool, out comes the excess of salt in the form of flaky crystals, not salt water crystals, not ice crystals, but pure salt, and this continues as the temperature falls until the remaining liquid holds 23.6% salt and it behaves as previously described. So that at—22°C. in the total solid condition we shall have a mixed lot of salt and salt water crystals.

No matter how we try we cannot get away from this 23.6% solution when dealing with salt and water. So in this way it makes itself of importance, having a definite composition and a definite freezing or melting point.

With water solution it is known as the cryrohydrate point or composition, and as metals and alloys behave on a similar basis but a different system, it is known in this connection as the "eutectic."

I want by means of this just to divert your minds so as to replace that water by pure iron ; and we are going to put into that iron, carbon : and accordingly as the temperature of the iron increases, so has the iron power of solution of a greater degree of carbon. When you see the blast furnace you get iron melting in the presence of carbon (coke), and at the maximum temperature, and it is just in that condition, and surrounded by those circumstances, where it can absorb or dissolve the maximum amount of carbon. The product of the blast furnace called "pig iron" is the beginning of all those materials known to us as steel, malleable iron, and cast-iron. If we consider cast-iron for a moment in the light of a carbon-iron alloy, assuming other constituents usually present exert no influence —which of course they do, just to the same degree as wives interfere, so do these. On our assumed consideration it will be evident that

the proportion of carbon which can be absorbed or dissolved in iron at different temperatures is a matter of importance. Just as water at boiling point is capable of dissolving the maximum amount of salt which separates on cooling, so iron in the molten condition will dissolve a large quantity of carbon, which on cooling, separates out in the form of graphite flakes.

Just as we have followed through the formation of three distinct types of crystals in the salt-water series, i.e., salt, salt-water, and pure ice crystals, so in the carbon-iron system we get graphite flakes characteristically shown in cast-iron: carbon-iron crystals, "the eutectic" most pronounced in white iron, steels, etc., those materials with strength and hardness; and pure iron crystals as experienced in low carbon steels, and wrought iron noted for their ductility. With variations of compositions and heat treatment all three varieties can be produced in one material at one time. There are, therefore, two states in which carbon occurs in ferrous materials, the free state, and that which is held in combination with iron. The contemporary to this latter state in the salt-water series is the cryohydrate composition of salt-water crystals. These two states of carbon very materially affect your cryohydrate composition of salt-water crystals. These two states of carbon very materially affect your machinery processes.

Supposing we were able (it is impossible, of course), to reduce the temperature of a super-saturated solution of salt in water, i.e., in excess of 23.6% salt, so quickly to — 22°C. that there was not sufficient time for the excess to separate out as flaky crystals, we should obtain a similar state of affairs which occurs in the carbon-iron system of the white iron of which hard samples of malleable iron are cast. The whole of the carbon is held in combination with the iron down to the solidification point, and the result is an extremely hard metal. You will, of course, understand by now if conditions of composition and cooling were suitable to allow some carbon to free itself and separate out as free graphite we should have the usual grey cast iron, but with what a difference to the machine-shop. The whole problem of producing malleable iron, either black or white, is to release that carbon from its combination with the iron, and to produce it in a free state so that after malleablising you are able to machine it with the freedom you desire.

In the manufacture of black heart malleable iron, the composition of the alloy is so arranged and the annealing carried out so completely, that the original structure of hard white iron carbide is entirely decomposed into nodules of graphite and free soft iron. The large mount of this soft iron present gives the material the characteristic softness for machinery, aided by the presence of the graphitic carbon which acts as a lubricant. During this process little carbon is removed, but is brought to this state of graphite.

In the case of white heart malleable, the malleablising treatment differs inasmuch as the glass-hard castings are surrounded by a packing material, in this case iron ore (iron oxide), which at the temperatue of the annealing, reacts with the carbon in the glass-hard iron carbide and removes the greater portion, leaving a much smaller number of graphite nodules distributed in the structure than in the case of the black heart variety. Further, in the place of the soft free iron of the black heart iron, a steely structure occurs in the white heart iron which contributes strength to the material, but not the same degree of softness nor ductility.

Production Requirements.

A fast cutting speed with long tool life is the secret of production to the engineer. Tool life, however, is governed under normal conditions by the working temperature, by the cutting conditions, and the material to be machined.

Machining difficulties can be divided into three classes :—

(1) The material may be of that nature that sufficient heat is developed in any given time to cause the tool temperature to rise rapidly.

(2) Spots of hard material may occur in the metal which would destroy the cutting edge of the tool.

(3) A heavy tangential load set up by the material on the tool point, sufficient to cause it to break without the failure of the cutting edge.

Imperfectly annealed malleable could provide all three causes of failure, as white cast iron exerts a very heavy unit stress on the tool point. Failure from the first cause arises largely from the " picture frame " type of iron, in which there occurs under the skin an appreciable layer of perlitic iron identical in composition and properties with annealed tool steel. The comparative hardness of this material with the tool itself is sufficient to explain the rapid increase in temperature, which would destroy the tool. Material in which the ferritic structure had been obtained through a complete dissociation of the pearlite, but small granules of the original hard structure is scattered through the ferrite, such granules, though harder than the hardest steel, are unlikely, because of their smallness in size and position in the soft iron, to increase the temperature of the tool or increase the load thereon, but by the constant rubbing with those grains on the surface, the tool has the cutting edge seriously damaged. This state of things can occur in both types of malleable and answers to Class 3.

Service Requirements.

Service requirements are extremely varied and depend upon the local conditions under which the material set up when the machinery is in motion, but may be supplemented by abnormal demands

brought about by lack of attention or even atmospheric conditions. The sum total of these demands have to be so well taken into account that designers usually make abundant allowance. Such mechanical properties as tensile strength, yield point, elongation, compressive crossbending, and shear strength, resistance to fatigue, impact, wear. Some of these various constants yield point, elongation, and ultimate strength, reduction of area, modulus of elasticity, and relationships between them give a very good picture of the behaviour of the material under static loads. From these constants, information can be gathered regarding its behaviour under dynamic stresses. The ultimate strength measures the load that can be sustained without failure, although with permanent deformation. The yield point producing visible permanent changes of shape in the material. Elongation and reduction of area are indicative of the amount of distortion a material can stand without fracture. The modulus of elasticity serves to determine the elastic deformation under relatively small loads.

Black heart malleable has an ultimate strength of 24 tons, white heart 28 tons per sq. in. Malleable iron of higher tensile strength would have a corresponding increase in the other constants to a very close relationship.

The tensile strength of malleable iron further varies with the cross sectional area of the piece, which in the case of white heart is much more definite than in black heart.

Porosity or unsoundness, the occurrence of primary graphite and the extent to which ferrite (soft iron) occurs in the structure, are factors which lower the ultimate strength of the material.

While black heart is, on the average, a few tons lower in tensile strength than white heart malleable, the elongation is much greater, being 20 to 25%, as compared with 6% as a maximum in white heart,

Compressive Strength.

The very ductile nature of black heart enables it to withstand transverse loading without failure. Well produced white heart will also stand much deformation before fracture, but the material does not flow in compression like a good black heart and will not stand cross-bending to the same extent without fracture.

Shear and Torsion.

These stresses involve the sliding of the metal on itself, the slip taking place along a series of planes within the material and shearing proceeds when the material is forced along lines in a direction at right angles to the axis. Torsion is an angular displacement not by a sliding movement of the planes within a solid, but by a rotating action, one plane over another.

Fatigue and Wear.

If the loads which have to be carried by castings were purely static, as those previously described, then many difficulties encountered would never arise, but instead of merely sustaining a steady load, they are subjected to shock of repeated reversals of applied stress. These dynamic stresses can be divided into two groups. One of these is characterised by impact rests of the Charpy type, where the stresses are in one direction only and of considerable intensity. The other group of stresses arises from reversals, repeated at times rapidly, sometimes of small magnitude, over an extended period. The Wohler type of testing machine is the nearest approach of reproducing the repetition of smaller stresses exisiting in specimens rotating and subjected to bending.

Tests made by both methods of testing show black heart malleable to be much superior in its resistance of shock without fracture. This quality arises from the presence of the soft and ductile ferrite occurring in the black heart, whereas the pearlitic matrix of white heart malleable does not so readily yield to deformation, but because of its slightly higher yield point, will resist greater shock stresses, but with greater danger of fracture.

Both varieties of malleable have the great advantage over many other materials in that the temper carbon granules operate as a hindrance to failure by fatigue. Failures of this sort frequently occur by the penetration of a crack at the grain boundaries of the metal, and should the crack proceed in the path of one or more of these carbon granules, its progress is impeded much the same as a hole drilled at the end of a crack prevents its further development.

Resistance to Friction.

The material having the greatest degree of this property is usually not the best for ease of machining. Experience has taught that the most successful bearing metal is that which holds a relatively hard constituent imbedded in a fairly soft matrix. The hard constituent takes the load, and the softer constituent wearing down a little, furnishes the means of holding lubricant. It is under these conditions of friction, with or without lubrication, that white heart malleable definitely shows to advantages over black heart, because it holds the harder constituent in the pearlitic matrix, whereas the black heart does not and cannot be regarded as suitable material to resist friction of any but a minor degree.

Discussion.

Mr. James Davenport (Chairman) said that he had to pay Mr. West the compliment of being very unbiased in regard to the two schools of malleable. It was his hope that there were representatives of both schools present, as he could not see either side sitting still after hearing the lecture.

Mr. C. T. Skipper said he did not remember the lecturer having made any mention of the relative distortion as between black and white heart. His experience was that less distortion occurred with black than with white. The lecturer had dealt with the relative merits of black heart, so far as the ease of machining was concerned, as compared with white heart and other available metals. He was desirous of knowing whether the lecturer considered that there was a definite need for both black and white heart malleable, as from a production point of view (which naturally he was most interested in) there was no comparison, black heart having the advantage every time; and seeing that there were other metals available to assist in production, he wondered if the lecturer thought there was a definite necessity for the two types mentioned.

Mr. West wanted to know what Mr. Skipper really meant by distortion, i.e., was he referring to distortion in the making of the malleable, or in the use of it?

Mr. Skipper replied that when black heart malleable was used in the shops it could be more accurately handled in jigs than white heart, due to the distortion which took place in the various processes.

Mr. West replied that undoubtedly that must be so, because in the white heart process it was necessary to get a so much higher temperature in malleablising that distortion was greater. That was one advantage of black heart. But he understood that the casting makers had straightening plants, and should have straightened the castings before sending them out. He did not think that anybody would seek to argue on the point of easy machining; it was so obvious. In fact why Europeans had been so long in adopting it was still a puzzle to him. He referred, of course, to production engineers. But undoubtedly things were moving quickly; there was a decided trend in favour of black heart.

The Chairman said that the discussion which had so far taken place had revolved round machinability. He would like to hear something about the question of quality, tensile strength, opposition to wear, etc.

Mr. West replied that he thought he had given favour to the white heart malleable in regard to tensile strength. The production engineer wanted ease of machining principally. In any case it was

not his pigeon to know the tensile strength of metal, but if he were doing his job properly, he could not be blamed for choosing the maximum of machinability. In his opinion the designing engineer would support that metal which would be best for the job. Black heart had been blamed, cursed, and put out of favour simply because people had not understood it. When you had 22 tons to play with, with a fatigue point of round about 12 tons, there should surely be sufficient lattiude for more of the article which would stand the usual stress or strain. On the question of wear, he wished to emphasise that it was impossible to have ease of machining and resistance to wear, as the two things were diametrically opposed. He preferred to ask : " Why not have a modified something which would take the place of the white heart casting ? "

Mr. Knagg wanted to know if there was any difference in the cost of the two malleables.

Mr. West said that he did not think there was much difference, as in his opinion the problem was pretty well squeezed to the bone. There was, however, a difference in the cost of production, if that was of interest. The man who held the " awkward baby " had the most expensive thing to produce. He could not play with a cheaper material like the black heart man. If he were starting at the present time, he would not think of white heart. Manufacturers were out to make money, whereas the making of white heart brings one nearer the poorhouse.

Mr. J. Ward referred to the respective carbon contents of the two malleables, and presumed that the black heart was the higher, He was interested in the question of abrasion.

Mr. West replied that black heart contained carbon to the extent of 2.4% and white heart, as produced in the cupola, about 2.9%. With reference to abrasion, this was more connected with the matrix to which he had referred, than with the presence of carbon. For instance, in the process of malleablisation the carbon was taken out, and when the final condition was reached, some would have been extracted ; so that in that event black heart would be better than the white ; at the same time it should be remembered that it was the body of the stuff which resisted frictional wear, and consequently the white heart, in his opinion, held the balance. With regard to hardening the surface liable to abrasion, white heart was more amenable to this. With black heart it was necessary to re-absorb some of the carbon, and this was not too easy, but with a modified black heart it was possible to heat-treat this up to 50 tons tensile, and obtain a face on the casting as hard as could be wanted. The point, which he wished to emphasise, because he felt it was a way out of this controversy, was that it was possible to produce something else which would answer equally as well as white heart.

MR. P. FASSOTTE said that the lecturer was quite correct in his statement that on the continent black heart was a comparatively recent innovation. In fact, he doubted whether before the war there were any firms at all making black heart, and in Belgium at the present moment there was only one firm handling it. In France, however, all the largest makers had all switched over to black heart. He thought the lecturer was wondering why Europe had stuck so long to the white theory. He thought the explanation was quite simple. It was a question of plant. Carbon of 2.4% required much more expensive plant than the 2.9% which can be obtained in cupola. He felt that the lecturer had been "blackballing" white heart so much that he thought a few of the advantages of the latter should be pointed out. White heart lent itself to brazing. He had never seen any black heart malleable being brazed, but possibly the lecturer might be able to say something about that, and also why the larger makers had concentrated on white heart and stuck steadfastly to it.

MR. WEST replied that he did not agree that plant had held the progress of black heart up. Rather the production engineer had. He was only now awakened to the possibilities of it. There was always ways and means of obtaining money for plant. There was a firm in this country now who had been making black heart for the past sixty years. He thought it was because they had been nursed in the production of black heart that they had never thought about white heart. With reference to brazing of black heart, he said it was not possible to braze because the Ferratic background just simply fused up and you could not get the necessary contact. White heart alone could be brazed of the two kinds of malleable, but this new modification of black heart could be brazed equally as well as white heart. He mentioned that conduit fittings, etc., had been ordered largely by the Government in white heart. H.M. Government would not have anything in the nature of black heart conduit fittings. There was the question of corrosion to be considered and he knew definitely that the Government favoured white heart from the point of view of offering more resistance to corrosion. Whether this could be borne out in practice he could not definitely state.

MR. C. C. HODGSON said that he held no brief for either, but he was afraid he could not support the case of white against black, because whilst there had always been a certain small field for the use of white heart, he felt it was fighting a losing battle against black heart, principally because the latter could be machined better. He did not think from a structural point of view its properties were so good. So many complications had arisen where white heart casting had been used for certain designs and they had been super-

seded by stampings. He thought the point was to make things as castings which cannot be made as forgings rather than anything else. There was also the question of wearing properties, he thought there was another way round that by which the production engineer could make the maximum use of black heart. This was by carrying out the major operations on black heart and then heat treating so as to produce a better matrix. This would suit the production engineer in some cases, because he had only to put the final machining on where required.

Mr. West asked Mr. Hodgson if he did not think that, if he started with a material which was not so delicate and awkward as white heart, it would be much more convenient. He wanted to know if Mr. Hodgson did not think that the semi-malleable would be more suitable in itself. Mr. Hodgson had arrived, or partially arrived, at the stage when he wanted to heat-treat; he thought this semi-malleable could be used because it was already in that stage without heat treating. If it was intended to go farther than that and get a greater hardness, then, of course, that material would produce it and produce it more quickly than the black heart, in connection with which it was necessary to re-absorb the carbon.

Mr. Hodgson replied that he would say on a casting where there was only a small amount of machining, semi-black heart by all means, but if there was a lot of machining he would say pure black heart would win on cost.

Mr. West thought that from the production engineer's point of view the white heart's day was very well measured.

Mr. J. Hood said he had listened to the arguments for and against white and black heart. He found from practical experience that a lot more castings were passed by inspection that were malleable castings; the percentage of rejects was definitely less. He hoped the lecturer could tell the production engineers present how to obviate the curse of the machine shop, i.e., blow holes or porosity and hard spots, which caused the tool room and machine shop people to have nightmare. He must agree with Mr. Hodgson—as the metallurgist had the last word—that, generally, the inspection department worried about things which they did not see and were not there. He could say that in his experience malleable had been machined very successfully, sometimes white and sometimes black, all to one end, namely, the inspection department had come along with their magnifying glasses and the metallurgist had had something to say about burning up, wrong structure, etc. He was afraid this type of discourse rather frightened the production engineer, who did not care so much how stuff was produced so long as he could machine it.

MAINTENANCE.

Paper presented to the Institution, Western Section, by F. R. F. Taylor B.A.(Eng.) Camb., Grad.I.P.E.

I FOUND this lecture presented some difficulty as the subject is open to so many approaches, the most important being: Plant engineer; equipment expert (maintenance tools are of special type); production engineer; designer (who stands in the maintenance engineer's view as his arch-enemy); labour manager (you will understand this later); and management.

The approach of the designer is a tempting one; I find the influence of design on maintenance extremely fascinating. As a rule, however, there are too many designers present at these meetings, and I have decided to take the wise course and handle the subject as I know it best—as a maintenance engineer employed outside the engineering industry.

Firstly, I wish to emphasise very strongly the importance of this subject to production engineers. Maintenance is the production engineer's first line of defence, and like defence in war, maintenance is " static "—it produces no results in the form of higher quantity or quality of output. Presumably no production engineer may buy—though he may often test—machinery incapable of producing to specification, but from the day he starts the new machine up, it starts to wear, and his reputation is indissolubly tied up with the ability of his maintenance service to see that production is held to the standard determined.

I am going to talk shortly of machines and more of men, because even with the finest equipment money can buy, the man on maintenance is the fallible human element to whom so many troubles are traceable and to a very great extent he settles the " class " to which his firm belongs. Frankly, to me, maintenance is a human and not a technical problem.

Machinery very soon divides up into two classes in the mind of maintenance engineers: (1) *Essential Machinery.*—Typical cases are plant that must operate at any cost, all day and night, such as public utility undertakings, electric power, gas, boilers and prime movers, smelting and blast furnaces, mine fans, or sometimes plant that must operate with absolute reliability at specified periods as aeroplane engines, ship machinery, lifts in tall factories, certain

chemical plant, " key machines in mass production. Also expensive manufacturing units having a high hourly rate, say, over £4 per hour, a typical case being paper-making machinery.

(2) *Non-Essentials.*—Such machinery being frequently installed in batteries or on intermittent and relatively unimportant duty.

The first class must be kept running at all costs. In general, it receives routine attention during running time (oiling, etc.) and any repairs immediately, replacements being carried out in detail over a long period of time to the small sectionalised units of which it may be composed. This is frequently rendered possible without a plant shut-down, by careful design allowing reserve capacity as in the case of the coal handling plant feeding a power house, in which case bunkers for up to six hours operation are frequently incorporated. Such plant often sets the designer a severe problem, in sectionalising into small easily handled units.

The second class is maintained in a more leisurely manner, often by replacement of standardised spares—a very satisfactory system. Usually such repairs are only carried out following a breakdown, either complete, or as a failure to maintain quality.

It will be seen that a maintenance engineer's specification calls for the following additional qualities from any machine: (1) That it can be maintained while in operation; (2) in small independent units easily handled and dismantled; (3) as far as possible the machine should supply its own power for servicing operations.

A common example is the surface grinder, which can be made to true up its own bed—undismantled, and the modern woodworking circular saw with a built-in grinder and tooth index.

Further, the maintenance engineer claims that the designer's duty is to produce machines which are: (1) Suitable for their job, i.e., the product must be right; (2) easily maintained. This may entail extra expense in construction but in the unusual case of a maintenance engineer buying machinery, this will be allowed for, on account of the benefits it gives. In my view a designer who neglects this point neglects his duty, not only to his firm, but to industry, as he saddles it with an unnecessary burden for which he will be cursed for perhaps thirty years—a solemn thought, gentlemen.

The equipment of the maintenance shop is, in its way, highly specialised, and I propose to discuss some of the more interesting items. In the first place the maintenance workshop of any factory is usually a dismal dark hole, frequently containing a horrible collection of old junk, machinery and stores. I believe this to be all wrong. Your maintenance workman represents a very high class of labour indeed, and to me it seems folly to saddle him with obsolete equipment and to waste his highly-skilled time driving machine tools that a general engineering works would have scrapped

years ago. A few firms—among them, I believe, Lever Bros. at Port Sunlight—are realising this and installing modern lathes in their maintenance departments.

There is another and stronger argument, however. Every maintenance engineer experiences certain black days when a production machine on an important contract fails, and the management demand that it be made to run again immediately. It is an unpleasant business breaking the news that the repair will take, say, fourteen hours, because the part needed has to be produced from oversize stock, and your best lathe will only trundle round at, say, 40 r.p.m., taking a light cut at that. After one or two such explanations he sets about finding reasons, such as the first given, whereby he may " win " something more up to date. I suppose that in the course of their tribulations, all maintenance engineers plan out the equipment for their ideal workshop, and I make no apology for giving the more interesting features of my layout. Some of them I had, others not, but all exist and are ordinary articles of equipment in engineering works.

You will realise, of course, that this workshop is planned for use in a factory other than an engineering works and one incorporating reasonably heavy items of production equipment, say, up to two ton units dismantled.

Workshop.—The shop itself with material and tool stores would be the largest and best-lit space that could be obtained.

Tools.—In the first place a really powerful straight roughing lathe using high-speed alloy tools. All work involving the removal of more than $\frac{1}{4}$ in. metal off the diameter would go on to this and be roughed down.

The next item would be a really good tool-room lathe. It must work to reasonably fine limits, say, plus-minus .00025 in. at a pinch, as no cylindrical grinder will be available, and it must be adaptable for almost any operation that can be done on a lathe.

A radial drill or a drill with a traversing table ; besides its normal functions this can be used for keyway cutting and certain light finger milling operations. Should drill to about $1\frac{1}{2}$ in.

A good shaper. This is a godsend to a maintenance shop—far more use than a milling machine. It is extremely adaptable for varied work and owing to the fact that it takes lathe tools is quickly set up and is capable of producing a really astonishing variety of work, cam cutting by eye to a scribed line, keyway cutting, planing, almost any operation that can be performed by a reciprocating tool being within its scope.

Serving all the heavy machinery and also a clear space for dismantling, an overhead runway and chain block for two tons.

A small surface grinder. This was originally intended for such work as sharpening special knives and, also, for a typical mainten-

ance job, production of thin steel washers to take up end play in shafts. It is invaluable for all sorts of jobs that could be worse done without it.

There must be the usual supply of hand tools, vices, tool grinders, etc. These call for no comment.

A forge is an absolute necessity (heavy jobs can be heated in the boiler fires) and a welder's outfit invaluable if a welder is available. But it will justify its existence if only used as a cutting tool. (I have seen casualties released with difficulty from machinery in which they had been trapped, and injured with hacksaws.).

Expanding reamers from $\frac{3}{8}$ in. up to 2 in. It will be realised that bushes are cheaper than shafts to replace and maintenance on worn shafts consists in cleaning up the ends of the shafts and rebushing below standard size. Occasionally, however, this is not feasible and the bush is reamed out—this frequently applies to link motions and oversize pins fitted. Or the bearing may be a " hole in a lump of cast iron," i.e., the main frame, for which there are no boring facilities. Again the expanding reamer ; shafts if expensive can be replaced fairly rapidly.

Seizures of all sorts give trouble in cleaning up. The motor trade has a tool for truing up crankpins in position. I should very much like to try one for seizures of the type which are usually cleaned up in position, with a file, put together and forgotten—if your conscience is so accomodating.

Other items of interest are, stores. Small stocks of high tensile steel should be carried, and more especially H.T. steel nuts and bolts, $\frac{1}{4}$ in., $\frac{3}{8}$ in., $\frac{7}{16}$ in., and $\frac{3}{4}$ in. Whit, being standardised.

Also socket head set screws, both of which are less liable to have their heads screwed off, leaving you with the job of extracting the remains with a hardened steel spike with a quick left hand thread.

Small stocks of stainless steel and Monel metal are of value where process work involving liquids or steam occurs.

Free cutting steel is valuable, if of good quality for rapid repairs, but it is a poor substitute for a high speed lathe and also expensive. The Izod value must be reasonably high, say 20 ft. lbs., and more difficult, the turners must be taught to treat it and their lathes brutally in an emergency.

Other items are " Snowdrop " pattern lamps, a heavy flat metal base, a stem of conduit tubing curling over at the top to a small enamelled bowl ; the appearance of the whole explaining the name given.

Portable gantries to handle up to say five tons on a 10 ft. span.

Lifting tackle, which needs special arrangements for checking and testing if accidents are to be avoided, and plenty of Samson trucks.

The next item may sound unusual, but it is quite as important as any of the others—a really efficient intelligence service. I will give you reasons and some suggestions.

(1) Remember that maintenance covers the infinite detail of the complete factory, not one department only, and the maintenance engineer never suffers by being well informed, preferably better and earlier than the management.

(2) Personal jealousies sometimes occur between foremen leading to failure to report trouble, and to the maintenance staff being blamed for failure of production output.

(3) New developments can be planned at leisure.

(4) It is a considerable help to know and be able to sympathise with the troubles of the production side. Their confidence is vital if the maintenance engineer is to do his work properly.

Such a system must be properly organised. It must, if possible, be unsuspected and its news absolutely up-to-date. (After all it is the duty of the maintenance engineer to visit all foremen looking for complaints). Juniors may be instructed to pass on all information, but they should not be encouraged to hunt for it. Cross-checking is often necessary and it is unwise to allow one source of information to find you cross-examining another. Information must be given willingly and preferably unconsciously, i.e., not as "intelligence," but simply as gossip.

The maintenance engineer must exercise very great discretion in the use he makes of this information. Obviously he may base action upon it, but he must never let it be used against the source from which it came. Occasionally items of intelligence must be neglected as being too easy to trace back. It is only when foremen and departmental managers realise that his discretion is to be trusted that the maintenance engineer is taken into their confidence to an extent that allows him to work as a really efficient member of the team.

This matter of intelligence leads naturally to the subject of men who form the real instrument by which the maintenance engineer, and indeed every manager, works.

Maintenance labour is composed of: Oilers, stokers and oddments (storesmen, etc.); fitters mates (and borrowed labour); fitters. foremen and chargehands.

Some characteristics noted are interesting. Oilers, often combining several other functions, as beltmen, stokers and labourers, must be extremely conscientious workers. Unlike the motor industry, the machine building trade does not enclose everything and then splash oil all over it. On the contrary. My men were responsible for about 250 machines, averaging approximately 30 oiling points each, looked after by three men. It says much for the class of man employed that I can only recollect about two seizures a year that

might be due to faulty oiling, it says more that I never found any single seizure that was not liberally smothered in oil. (Showing that other intelligence services than my own also existed). Seriously though, this illustrates another requisite for a good oiler, he must be on friendly terms with everyone in the departments in which he works. If his presence causes the operatives to seize blunt instruments with unkind intent, he cannot hope to do his work properly. Frequently machinery must be stopped for oiling, no one likes this, but unless it is done instantly the oiler cannot keep any sort of timetable, so his personal character obviously has considerable importance.

The next distinct class is the fitter's mate, frequently noticeable by an officious air of knowing more about the job than the fitter, and a distinct inclination to give orders and advice to all and sundry. In point of fact, he is an extremely hard worker—surprising things are done by man power alone, and you realise his value when you watch him on a job, a sort of third hand and eye to the fitter. More so, on those unpleasant occasions when you are informed, " Maintenance is costing too much—who will you sack ? " Not put quite so crudely, of course, but it amounts to the same thing. Always a fitter's mate whose value you realise when you watch your fitter working with someone from the general labour pool. No third hand and eye business now. When the general labourer has been trained to some sort of competence you manage to win back your own man. Next time he goes the labourer has gone—or proved so valuable he cannot be spared so the whole cycle is repeated.

The fitters form a distinct class by themselves. In maintenance it is customary to give a fitter a repair job, somewhere out in the factory, to discuss it if necessary and then forget it completely, leaving him to think and work out his own salvation, often having to satisfy an extremely cantankerous production operative or chargehand, " Machine just broke—weren't repaired properly when that other part broke—ain't done nothing wrong meself," i.e., he has, in fact, brutalised it in some way for the thousandth time and the inevitable has happened again.

Such fitters are not common. Just to what extent, you will understand when you reflect that a foreman is selected in production work for his ability to think out the minor problems of a couple of dozen men, frequently of a simpler nature. Very definitely your maintenance fitter has these foreman's characteristics. He can think a problem through, usually correctly. He has views and opinions which he is able and often only too willing to express and defend. Finally, he has real skill and initiative.

As a group, then, not at all easy to handle, in fact especially on those occasions when a problem has been thought out wrongly, very difficult. The easiest method on such occasions being, " As I

am responsible for your work, I think we will do it my way," leaving the question of right and wrong to be decided at leisure. Later, when you understand their idiosyncrasies you learn to be proud of your gang.

Foremen and chargehands form three distinct types. One type has been selected because he is obviously head and shoulders above his fellows technically and has some other necessary qualities. If he is not handled carefully you may lose a good workman for an indifferent foreman. The second class is the leader born,—makes an excellent foreman if left to himself, but often has something in him of the swashbuckler and bully. The third type is interesting. Most workmen are terrified of paper, invoices, advice notes and the like ; the fact that a possible candidate has ability in this direction may turn the scales in selection. Well handled from above such a man is not a bad foreman, but a cross between a rubber stamp and a recording angel in the less successful cases.

Other categories coming under the maintenance engineer are : Plumbers, waging a perpetual war with the fitter as to what work they may and may not do. Is a defective steam valve plumbers or fitters work ? Carpenters who are ranked, surprisingly, by the maintenance engineer as "experimental staff." In a factory of the type under consideration the direction is usually non-technical, certainly in the engineering sense. When working on new developments it is not sufficient to show them a page of figures, two graphs and a blueprint—usually they cannot interpret them, and when they can they are not convinced. They want to see something going through the motions. Such a model need be of no great accuracy and will have a working life of say, half an hour, by which time it will be either condemned or approved. A carpenter can produce such articles in about a quarter, or less, of the time taken by a fitter. Besides his obvious job—looking after the wooden parts of the building, doors and floors particularly, the carpenter is a genuine standby in times of real trouble—when the important production machines break down. Many machines with cracked and broken parts have been faked up by means of props and wedges to finish their day's run.

Finally, there are the electricians, who are the same sort of nuisance to the maintenance engineer that maintenance engineers are to the management. You must realise that often the maintenance engineer is, in fact, the cause of considerable trouble, receiving contradictory orders from the chief engineer and from the production management,—a situation that needs extremely careful handling, to say the least of it. The trouble with the electrician being that he owes his allegiance to the chief electrician and also that he lives in a hole even darker and more full of junk than the maintenance

workshop. Finally, he can never be found when wanted, switching off the power being the only way of getting hold of him quickly.

To handle this staff it is necessary to have a simple, flexible and reliable system of issuing work. Each system must be worked out to suit local conditions ; I found that giving the foreman the right to use his discretion in an emergency, and insisting on him doing so, but otherwise compelling him to get my signature before starting work, coupled with the usual entry of times, etc., on the back of the card, satisfactory.

What of the maintenance engineer himself ? I have shown that maintenance is of two classes, routine, from oiling to periodical replacement of parts, and emergency, repairs to damaged and worn machinery.

Routine is a matter largely of having a time table and of collating reports from oilers or operatives, and to-day emergency repairs are frequently simply a matter of replacing spare parts or of the standardised overhaul, cleaning up wearing surfaces, and rebushing. I feel strongly that such work does not call for the whole-time services of a trained engineer. They cannot, for once he and his men are familiar with the machinery all work on it can be classified as above, and the issuing of instructions he can do almost in his sleep. Yet his presence is necessary to deal with major troubles.

In my view the maintenance engineer must—and from experience, usually does—justify his existence otherwise. There are several possibilities open to him. He is well placed to study and take part in management and production. Or he can work on research and development, possibly his most fascinating opportunity, if a little uncertain. Or he can justify his existence as a specialist. Speaking personally, I made a special study of the following : (1) The production of copper cylinders to limits of plus/minus .0015 in., having a mirror finish. (2) Air conditioning, especially in regard to printing. (3) Sharpening and behaviour of guillotine knives up to 6 ft. long with a razor edge over the whole length. (4) The behaviours and troubles of automatic guillotines. (5) Gas masks. We had an ammonia refrigerator as well as other applications and found it extremely difficult to get our men to wear masks. It was usually necessary to wear one oneself, even though out of the gas zone. Others I know worked on the moulding properties of rubber, and studied the Bedaux system, to quote two diverse subjects. Opportunity here is ample and the subjects dictated by the trade and personal inclination or discretion.

In addition to this work the maintenance engineer must take place in the daily triangular fight : Management, maintenance engineer, maintenance services, supervision of production, both as a link and a barrier. It is only here that his daily work becomes difficult. Factories seem full of supervisors, perhaps less competent

than they might be, all only too anxious to force maintenance to carry the blame for their shortcomings. If the mantenance engineer leads his staff properly, praise, very rare indeed, is passed on from the management, blame at his own discretion, as only he knows the facts: for the same reason his censure is given quite gratuitously and without any authorisation from elsewhere. He must take on himself more than a full share of responsibility for the work of his men for whom it is his duty to act as a shield against anything but the most fully justified complaint. The initiative of the maintenance fitter is his chief asset, the very reason for his being employed, and he must not be penalised for using it, and he must know this —from experience.

You will realise that there is some justification for the advice given me by a friend: "What you have to learn on this job is not to be an engineer but a ruddy diplomat." As examples in diplomatics, I soon found it all too true, to quote again, "that anyone who owns a car thinks he knows all about engineering." In consequence I used to find that I had no sort of control over my men, instructions being given by office boys, machine operators, foremen, departmental managers, welfare workers, and others. This rather chaotic state was remedied by the jobcard system, which in detail worked as follows: We were authorised to do no work except against a written requisition; this worked quite nicely when it was realised that we really meant it, and after we had let a few jobs lie till they rotted for want of requisitions. There was one catch, departmental managers developed a bad habit of giving verbal orders for work required, to the maintenance foreman, he, poor man, not being in a position to refuse, or even to refer them to me without giving offence. We finally arranged that he could accept such orders—any number of them—in the most gracious manner, but that, subject to his own discretion for emergency work, he would not proceed except on my signature of the requisition we had written ourselves to cover the work. This meant that when necessary I went and argued it out, and my foreman could continue with the management, on the best of terms.

Very quickly the maintenance engineer finds certain human weaknesses in his associates that lead to perpetual trouble. A very common one is the "desire to see the wheels go round." It operates thus. You, the maintenance engineer, are requested to make arrangements say to raise and lower very occasionally a cast iron table 2 in. and you find that the easiest and cheapest way is to use wedges and a hammer. If you are so foolish as to do so there will be a storm of protest, "Not engineering," "Want something better," and so forth. In vain to point out that your scheme meets all requirements and is cheap; you will eventually have to install four jacks or a system of rotating cams. It is extraordinarily diffi-

cult to get it into the lay mind that wood is an excellent engineering material. For this reason the demonstration models mentioned earlier are better painted with, say, aluminium paint. Throughout you will find that the simple solution of any problem is not so well received as a complicated and gadget-loaded one. A most distressing state of affairs, for in a maintenance workshop it is always difficult to get anything built at all, and equally difficult to get money to put work out.

Another difficulty that frequently occurs is to decide how far a machine can be pushed, either by straight overloading or more frequently by producing above nominal maximum size. This I consider a sales problem, but it is a very serious and real one for the maintenance engineer nevertheless. Machine designers in this country have a bad habit of allowing ample margins and it is often desperately difficult to decide how far a machine can be taken past nominal maximum capacity. You have no drawing, and stress data is usually of the vaguest, if existent at all. Continental designers are better in this respect, they are not afraid to state outright maximum speeds, sizes, and loads that are genuine—if not optimistic.

Desire for power and prestige are human failings, well recognised. They somethimes lead departmental managers to apply for the exclusive servcices of a fitter to be trained as a specialist. After bitter experience I am absolutely opposed to any scheme involving the turning of honest maintenance workers into specialists. The maintenance fitter must be able and willing to tackle any job that comes—he is selected and paid with that end in view. When he specialises in one department usually on one set of machines, several unpleasantnesses follow just as surely as he acquires exceptional skill in handling these machines. The department looks upon him as their own property and make trouble when he is required elsewhere.

There are almost invariably disciplinary troubles. From whom shall he take his orders ? From one of several rival charge-hands, from the departmental manager, or from the maintenance foreman ? His knowledge and skill are considerably greater than that of the machine operatives. He spent much time making petty adjustments they are too lazy to make themselves—should he be of amiable enough disposition. Similarly, he is called in to petty discussions of machine troubles which the operators can quite well settle without his assistance.

There is a subtle effect on the man himself ; the machines on which he specialises are the main object of his existence, and all other work easier or more difficult is—well, outside his professional status. It is easy to see that a maintenance workshop full of specialists would be badly disorganised by the absence of one member,

and the introduction of new classes of machinery will cause friction and personal jealousy. To my mind the maintenance fitter is seen at his best and gives his best service as an all-round competent workman. An unusual type and correspondingly valuable, it is well worth the spending of time, thought, and effort in leading him.

Finally I wish to stress again that the maintenance engineer's job is to enable production to continue, technically a simple matter, but, outside the engineering industry, he must learn to do his work understaffed and poorly equipped, sometimes in the teeth of well meant hindrance from the management, and the service demands made on him call into play something that no scholastic qualifications give—the art of personnel relations.

Discussion.

MR. ROWBOTHAM : Mr. Taylor certainly seems to have seen and experienced some of the hard things in maintenance. I don't know whether we have any maintenance engineers amongst us here ; if we have, I am afraid they will not think the lecture was very encouraging.

MR. CLINTON : I think Mr. Taylor has given us a very interesting lecture especially from the domestic point of view.

In the maintenance department described by Mr. Taylor, was there any incentive system of payment on any of their jobs ? In the event of the production workers receiving bonus, does the maintenance gang responsible for the upkeep of the production machines share in that bonus ?

MR. TAYLOR : We did not have any bonus system. We pay reasonably well, round about 75s. to 80s. and more, which is high, as engineering pay goes. The problem of the worker on bonus on a machine which must be kept in condition is, that he is much more anxious just to keep the machine going and earning than to have it stopped and put in good condition, which would allow him to increase his earnings.

MR. DANIELS : I have had a good deal of experience on plant of varying age, and I think the maintenance engineer may be very valuable in this way. When a seizure or stoppage takes place calling for his attention, he should try and bring the particular machine up-to date. I think it can be very valuable if when a machine passes through the maintenance engineer's hands he deals with it in this way. The maintenance engineer's job is a very difficult one, and I think Mr. Taylor has given us a very interesting paper indeed, one on which a good many questions might be raised.

MR. TAYLOR : The question of bringing machines up to-date receives attention, but this is not often very easy, in the printing trade especially, you do not always know what your competitor is doing. If you know that you try to bring the machine into line with the latest practice, but very often you don't know and have to carry on in the light of your own intelligence.

MR. BURGOINE : I have been very interested in Mr. Taylor's talk to-night, and I think we all have learned something from him, but he seems to have dealt with the subject almost completely from the point of view of running plant. I think he will agree that the maintenance man is sometimes called upon to install new plant.

I think he should have added one or two things to his list of tools. One thing I would suggest would be one or two light pneumatic road breakers or drills to break up concrete foundations. I have

noticed in more than one or two firms the workers have to break up concrete with hammers and chisels, and I think a much better and quicker job could be done with the pneumatic breakers. Another useful thing is a good spirit level ; I mean a really first class one costing perhaps £10.

In these days we all drive machine shops by electric motors and the electric motor is regarded as a pretty reliable proposition, but I would like just to mention something I heard a few weeks ago. I saw a big plant running a refrigerator with a 500 h.p. steam engine, and a 200 h.p. motor was driving another refrigerator. I asked what was the comparative reliability. I was told that last year they did not stop their steam engine or even slow it down once during their season, the engine running continuously for seven months. This year it was running all through the week and stopped at week-ends. The output had to be increased, so they installed the motor set, and were running the motor all day and stopping it at night and during the week-ends. They had five complete forced stoppages of the motor during the seven months season. So it does not seem the electric motor is quite so reliable after all.

With regard to what Mr. Taylor said about the use of free-cutting steel, I entirely disagree with him. If a machine breaks down it is usually due to, first, bad design ; second, unsuitable material ; and third, improper handling. Now if a part has broken or failed, due to bad design, poor material, or even through unfair treatment, it would be better to use better rather than poorer material, so that rather than stock cheap free-cutting steel, I would stock nickel steel or nickel chrome steel.

Then he suggests a stock of expanding reamers. The expanding reamer is a useful tool for some purposes, but an expanding reamer of the ordinary type would hardly produce the kind of bearing in which a high speed shaft would run truly, I think a grinder is another thing he wants, and also electric drills. I mention these tools as the paper may be published, and the lecturer might like to make additions to his own list.

Mr. Taylor : I must admit that the list of equipment I gave was not by any means complete. I rather tried to pick out the high spots on equipment. I quite agree on the subject of the pneumatic breaker. But I know someone who installed one and had quite a lot of trouble as to who should use it—that is, was it a fitter's or mason's job ? I quite agree about the spirit level. We had one but not quite as expensive as the one mentioned. With regard to the use of free-cutting steel. Firstly, we choose a reputable brand of reasonable strength and properties, and secondly I would suggest that you have never been in the position of maintenance engineer with an agressive management behind urging instant repair. Under such compulsion

some astonishingly makeshift repairs are carried out! Usually a properly executed repair in good material is later substituted. I was not often suffered to do much more than repair work. Actual maintenance was quite an uncommon thing with us, and a great deal of this free-cutting steel was used on shafts of which sometimes nearly ¾ was completely worn away and the machine was still running, very often on drives on which great accuracy was not called for—merely transmitting motion. With regard to expanding reamers, I am sorry to fall foul of you, but I found them very useful and satisfactory.

Mr. Hingley: I have been a maintenance engineer for about thirty years, and I don't want to ask any questions. There is quite a lot about the job I want to forget, but I would like to take this opportunity of paying a tribute to the maintenance engineer—I mean the genuine one. I am the head of a firm that does practically all maintenance, and I can assure you that this class of operator is amongst the finest this country produces. They have all-round training, have to use a lot of initiative, and are thoroughly trustworthy, and the problem is how we can replace them. It has been my privilege to occupy positions as maintenance engineer in very large firms, and I have found the finest maintenance men are those who have risen from the bench. You do not want highly technical men with university degrees. In many large firms they have increased their costs enormously by taking on young men from colleges. The finest man is the man from the bench, and I am glad to pay a tribute to the men who do the hardest part of engineering.

Mr. Taylor: I thank you for that, as I yield to no one in my admiration for the class of fitter under my charge, and I agree they have the hardest job—all kicks. I think that in many points you rather bear out my contention that for such as myself maintenance is not a job on which one is justified in spending one's whole time.

Mr. Banner: Does Mr. Taylor not think it possible for maintenance to be overdone by the heads of the firm? Their one idea sometimes seems to be just to get a machine running again, when it might be better to cut the loss instead of keeping on paying for repairs on a machine which is really worn out. One instance I remember where an engine was kept running. It got into a terrible state, but it just kept on until it burst its water-jacket. I think in a case like that if a machine was replaced with a new one it would earn its cost in a few years.

Mr. Taylor: I quite agree that this is so, and in point of fact I have known of it being suggested that if an accident could happen to a certain machine no questions would be asked.

Mr. Hobbs: The lecturer talks of repairs and keeping a machine going at all costs. Does he not think it would be better if a machine was taken out of the work and overhauled at certain intervals?

I know a firm where a system was employed of keeping spare machines so that whatever happened the job was kept moving. In the case of a breakdown you just moved the work over to a spare machine.

Mr. Taylor: I would like to know the name of that firm. I personally cannot conceive of a departmental manager having a machine and not using it.

Mr. Hobbs: No machine was allowed to be used after a certain period. It was taken out and overhauled.

Mr. Daniels: Following the last speaker, some years ago we put out a number of pumping plants for Canadian railways. I went out to see them. In all cases they were in complete duplicate, and I found in every case everyone was working to full capacity. I found gas engine driven pumps that had not been stopped for seven months. I protested, but was told they had got to go on working until they broke down. All they did was to put in a barrel of oil and run the whole of the duplicate plant for twenty-four hours a day, seven days a week to full capacity.

Mr. J. L. Daniels: I should like to sympathise with Mr. Taylor over plant. We once installed some plant in a chemical works in the Midlands. After six months they wanted some modifications to the design. It was arranged that we should have the maintenance plant, and do the job over the week-end. During the Saturday afternoon the machine was taken out. It took two of our mechanics the whole of the Saturday afternoon to put the lathe right.

Mr. Banner: I know two haulage contractors, one of whom believes in buying a lorry, loading it to full capacity, running it until it breaks down; then repairing it and running it again. The other believes in buying a lorry, loading it carefully, keeping the load down to the correct weight, overhauling it regularly, and, after a certain period, replacing it. Both men are saving money. which is right?

Mr. Taylor: Obviously the answer is, that if both men are making money, then both must be right!

Mr. Organ: I imagine that one of the most important parts in maintenance is its actual cost, and in large firms where they employ large and expensive plants, this particular subject comes up for review periodically, and it is usual in many firms for the maintenance engineer to be supplied with monthly costs of maintenance, together with statistics showing what each machine cost in maintenance. Was the speaker in the habit of receiving such information? From such information the cost of maintenance can be tabulated, and a machine which is becoming uneconomical from the point of view of repair can be thrown out, thus saving a considerable amount of expense.

Mr. Taylor: I was in the unhappy position of receiving costs of maintenance, and it was usually pointed out that these were much higher than before, but I was not in the happy position of having enough clerks to work out the cost of maintenance on each machine. This would have taken a fairly large staff.

Mr. Rowbotham: Mr. Taylor has tackled the subject from one particular angle, but maintenance does vary so much from factory to factory and from one type of plant to another. The type of plant maintenance in, say, a transport undertaking is entirely different to the problem of maintenance of a very accurate machining plant such as instrument work, and that is again different from the type of maintenance required on general engineering work. I suppose it would have been quite outside the scope of Mr. Taylor's paper and quite impossible for any one speaker to go into the variations which must occur in these different works.

One point raised by Mr. Taylor was that the maintenance shop was usually a very hole-and-corner sort of place. I think this is largely true. I have been into many factories, some of them very fine undertakings from the point of view of production, but the maintenance department was not a thing to be proud of. I am not sure if one starts off with a clean-looking, well-planned maintenance shop, that it is really as efficient as when it looks more like a marine store dealers. I think that the hole-in-the-corner look sometimes covers such a very varied stock that old George can always produce "the rabbit out of the hat" and get a machine going again, in a way that could not be done by some cleaner-looking departments.

Mr. Taylor mentioned some machines with 50 lubricating or greasing points on each. Did he ever try on any of these machines any system of "one shot" lubrication, in which various points are brought to one centralised spot? This has been tried and is used on motor cars and other machinery, and I am not sure whether it is always as satisfactory as the sales engineer claims. I think there is some danger of certain of the pipes or points getting clogged, and so not so certain of receiving lubrication as if the lubricant was applied individually. Now, I would like you to join me in thanking Mr. Taylor very cordially for his paper.